(12) **UK Patent Application** (19) **GB** (11) **2 359 368** (13) **A**

(21) Application No 0003804.2

(22) Date of Filing 19.02.2000

(71) Applicant(s)
The Secretary of State for Defence
(Incorporated in the United Kingdom)
Defence Evaluation and Research Agency, Ively Road,
FARNBOROUGH, Hampshire, GU14 0LX,
United Kingdom

(72) Inventor(s)
Stephen William Mahon

(74) Agent and/or Address for Service
Anthony Oliver Bowdery
D/IPD (DERA) Formalities, A4 Bldg, Ively Road,
FARNBOROUGH, Hants, GU14 0LX, United Kingdom

(51) INT CL⁷
$G01N\ 11/16$

(52) UK CL (Edition S)
G1N NABA NADE N1A3A N3V5 N4D N7P

(56) Documents Cited
GB 2342445 A   US 5710374 A   US 4704898 A
Patent Abstracts of Japan, JP 59 0099332 A WPI Acc.
No. 86-237939 & SU 1 210 077 A

(58) Field of Search
UK CL (Edition R) G1N NAAJI NABA NADE
INT CL⁷ G01N 11/16
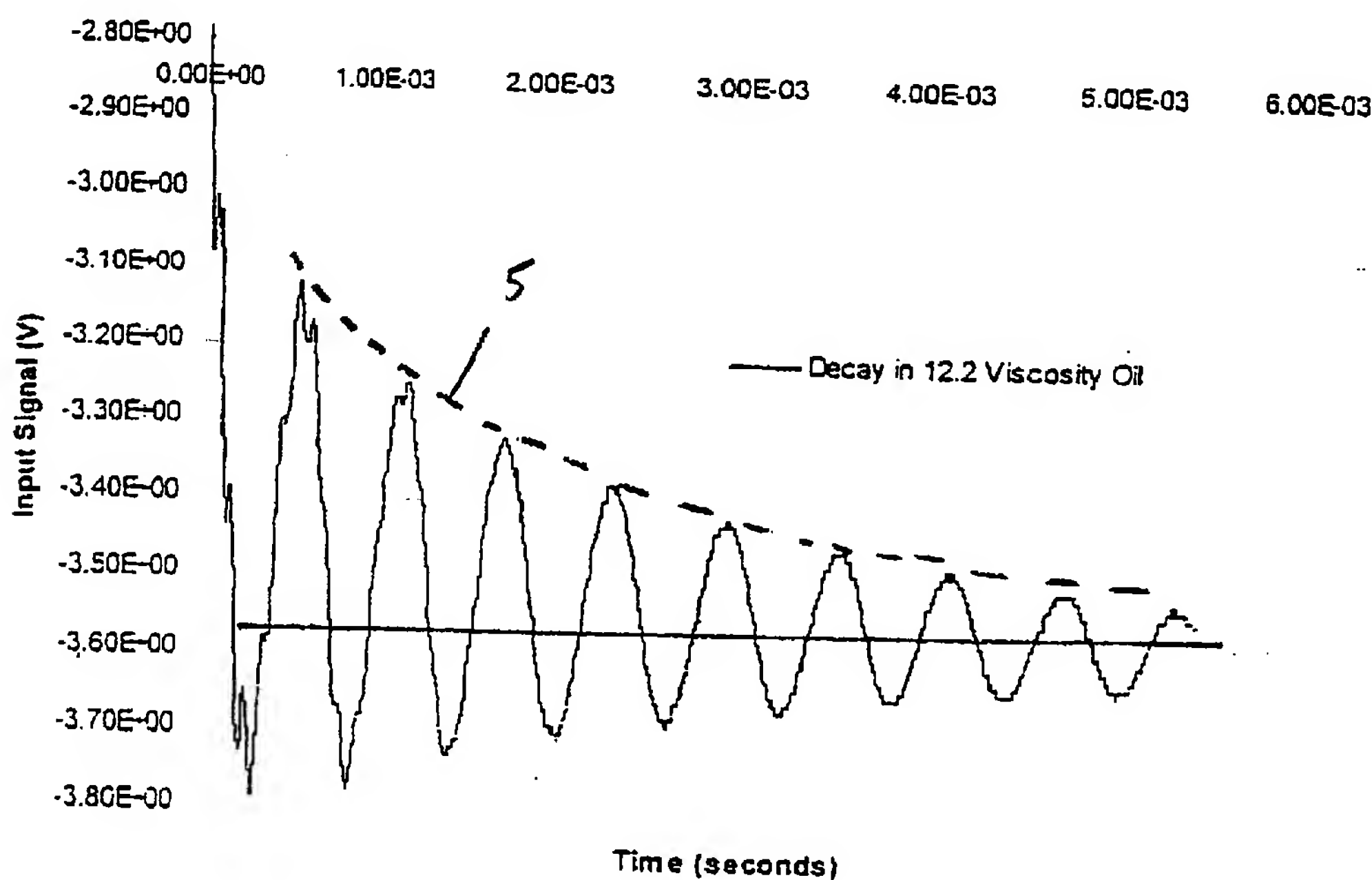WPI, EPODOC, JAPIO

(54) Abstract Title
Determining the viscosity of a fluid from the exponential decay of an excited piezo-electric element

(57) A method of determining the viscosity of the fluid by the steps of: determining a linear relationship between viscosity and a constant β, releasing the piezoelectric element and measuring the voltage produced, determining the constant β from the exponential decay of said voltage where

$$V = V_0 e^{-n\sqrt{\beta}},$$

V being voltage produced after n oscillations after a point in time when the voltage is V_0 and then from β, determining viscosity of said fluid.
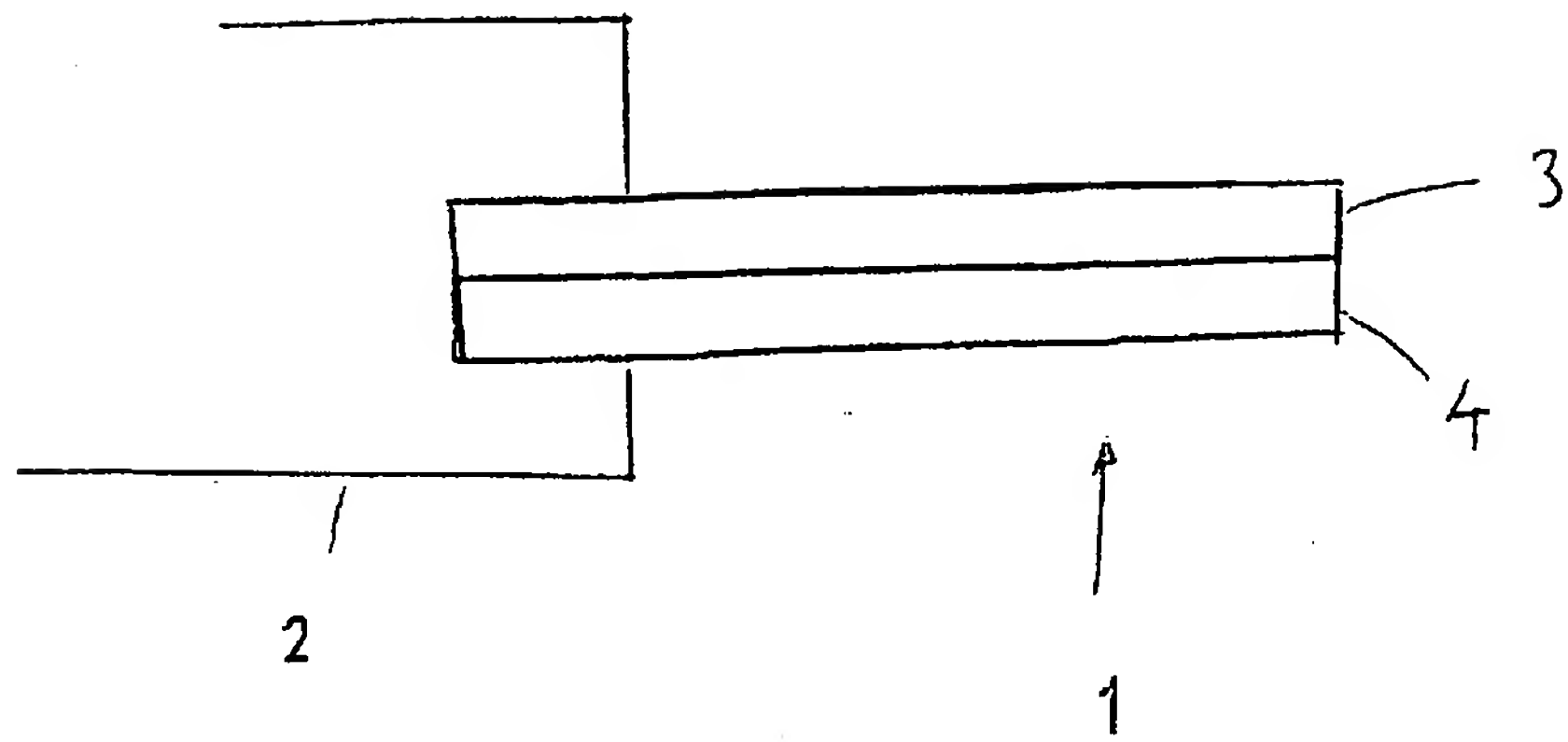
Fig 2

GB 2 359 368 A

Fig 1.

3

4

2

1

Fig 2

Fig 2

-2.80E+00

0.00E+00 1.00E-03 2.00E-03 3.00E-03 4.00E-03 5.00E-03 6.00E-03

-2.90E+00

-3.00E+00

-3.10E+00

5

-3.20E+00

Input Signal (V)

-3.30E+00 ——— Decay in 12.2 Viscosity Oil

-3.40E+00

-3.50E+00

-3.60E+00

-3.70E+00

-3.80E+00

Time (seconds)

Chart3

Figure 3 Calibration Chart
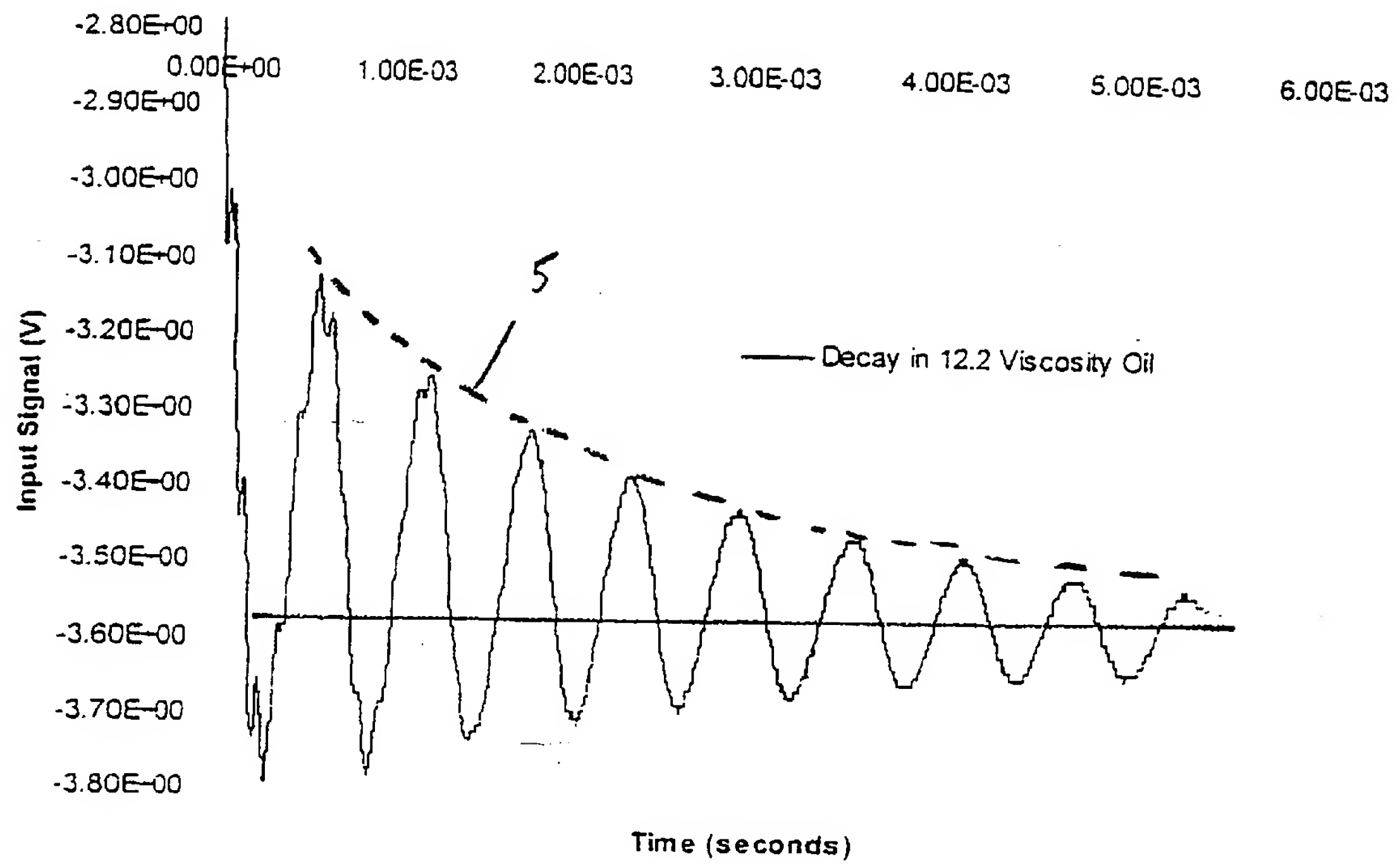

$y = 0.0013x + 0.0017$

$R^2 = 0.9961$

Viscosity (mm²/s) at 40°C
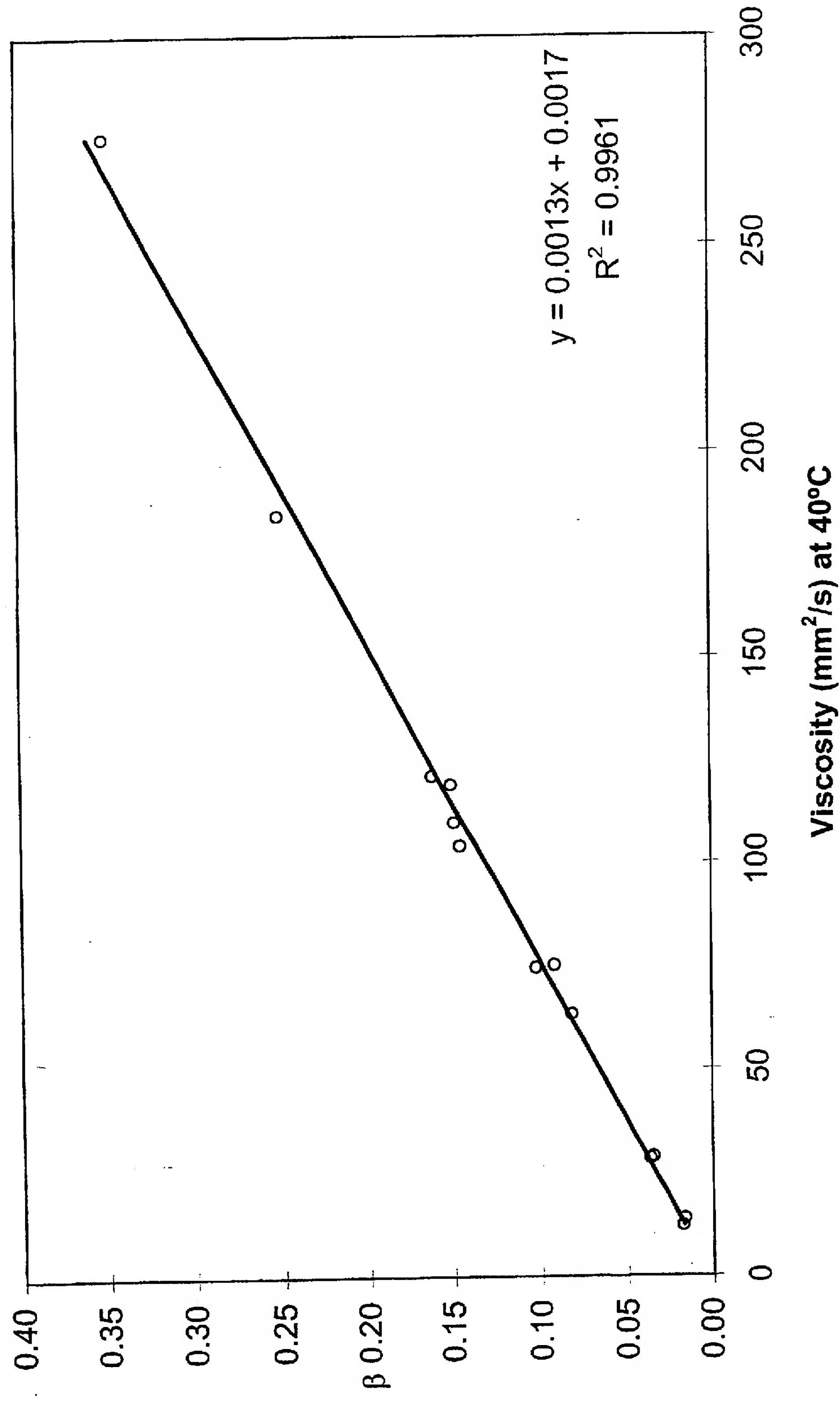
○ Linear

Method of Determining Viscosity

The invention relates to a simple and effective method of determining the viscosity of a fluid and in particular to a such a method using piezoelectric elements.

Traditional viscometers are based on measuring the drag experienced by a body moving through a fluid. Such methods of measuring viscosity are often bulky, expensive and difficult to use.

It is known that measurement of the damping of a piezoelectric oscillator can be used to measure fluid properties at low viscosities. The measurement is based on the principle that when an oscillator is immersed in a fluid, small displacements of the crystal induce a boundary layer which generates shear in the fluid. The reaction of the transducer is to increase its effective inertia, thereby decreasing the resonant frequency and increases loss in the resonating system. Solid state devices such as piezoelectric resonators are known for measuring viscosity. The frequency of oscillation of piezoelectric elements can be measured and when immersed in fluid, changes in frequency of oscillation are proportional to the damping ratio of the resonator and thus a measure of the viscosity of the fluid. Alternative systems examine the variation in phase and amplitude of travelling waves across piezoelectric materials.

However in some applications, such as determining sensitive changes in viscosity in engineering oils to ascertain degradation, commercially available viscometers are not accurate as oscillation causes shear thinning effects arising from their high frequency of operation. Additionally, at these high frequencies the amplitude of

oscillations small compared to the diffusional distances and particle sizes and therefore does not give a macroscopic measurement of viscosity.

US patents 4799378 and US 3943735 both describe the use of piezoelectric elements and their use in measuring viscosity. The problem with the methods described to determine the viscosity is that they are complex and do not lend themselves to quick effective implementation requiring the minimum of computation.

It is the object of the invention to provide an accurate, small and inexpensive viscometer which avoids shear thinning effects which is accurate and sensitive and capable of operating in high temperature and pressure environments. The inventor has overcome these problems by formulating an effective method to determine viscosity by mean of a simple relationship. This simple and inexpensive device allows the use of such a fluid condition monitoring sensor in large volume applications and in harsh environments, neither of which are possible with existing systems.

The invention comprises a method of determining the viscosity of the fluid by the steps of:

a) determining a linear relationship between viscosity and a constant β,

b) inserting a piezoelectric element into said fluid and exciting said element to cause it to deflect;

c) releasing the piezoelectric element and measuring the voltage produced,

d) determining the constant β from the exponential decay of said voltage where

$$V = V_o e^{-n\sqrt{\beta}},$$

V being voltage produced after n oscillations after a point in time when the voltage is V_o

from β and step a) determining viscosity of said fluid.

The invention will now be described with reference to the following figures of which:

Figure 1 shows a piezoelectric element suitable for use in the method of measuring viscosity according to the invention.

Figure 2 shows the damped oscillation of a released excited piezoelectric viscometer.

Figure 3 shows how energy dissipation is linearly related to viscosity.

Figure 1 shows a representation of a bimorph piezoelectric viscometer, cantilevered onto support 2. The bimorph comprises two individual piezoelectric elements 3 and 4 sandwiched together. This ceramics are chemically bonded by sintering them together with a metal-loaded ink. This allows them to be used at high temperatures where adhesives would be non-linear or fail.. The elements are electrically polarised in opposite directions. As is clear to the skilled person electric excitation will cause the bimorph to bend. Such a configuration allows large bending amplitudes and has low resonant frequencies.

A pulse signal is used to deflect the bimorph and using a charge or voltage amplifier in series with the bimorph, a signal from the bimorph as it decays. On releasing a strained piezoelectric element such as that of figure 1, it will undergo damped harmonic motion as shown in figure 2. The damping motion can be described by the intrinsic damping associated with the bimorph and the external force of the fluid in which it is immersed. In most situations the extrinsic contribution will dominate and allow the determination of the viscoelastic properties of the fluid to be determined from an analysis of oscillatory decay of

the bimorph. The more viscous the fluid, the more damping and the quicker the decay curve flattens out. By measuring the decay constant the viscosity of the fluid can be determined. The decay curve can be described by the general formulae $V = V_o e^{-n\sqrt{\beta}}$, where V_o is the voltage at a particular point in time and V is the voltage at n cycles thereafter, and β is linearly related to viscosity of the fluid as shown in figure 3. V may be suitably measured by measuring the voltage peaks. Essentially $V_o e^{-n\sqrt{\beta}}$ describes the envelope 5 of the signal (fig 2). β is linearly related to viscosity of a fluid and the viscometer may be calibrated by measuring β at two points, e.g. in air, water or with a standard oil of known viscosity. Figure 3 shows how energy dissipation is linearly related to viscosity.

Claims

1. A method of determining the viscosity of the fluid by the steps of:

a) determining a linear relationship between viscosity and a constant β,

b) inserting a piezoelectric element into said fluid and exciting said element to cause it to deflect;

c) releasing the piezoelectric element and measuring the voltage produced,

d) determining the constant β from the exponential decay of said voltage where

$$V = V_o e^{-n\sqrt{\beta}},$$

V being voltage produced after n oscillations after a point in time when the voltage is V_o

from β and step a) determining viscosity of said fluid.

2. A method as claimed in claim 1 wherein step d) comprises measuring the voltage at peaks.

3. A method as claimed in claims 2 or 3 wherein the electrical excitement of the element and the measurement of output voltage die to subsequent oscillation of the element is performed via the same terminals on the element.

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1N(NAAJI, NABA, NADE)

Int Cl (Ed.7): G01N (11/16)

Other: WPI, JAPIO, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X,E	GB 2 342 445 A (Buchanan) Whole Document	1-3
Y	US 5 710 374 (University of Virginia) Whole document	1-3
Y	US 4 704 898 (Ernst Thorne) Figure 1 and abstract	1-3
X	Patent Abstracts of Japan 2 October 1984 & JP 59 099 332 A (Nippon Jidosha Buhin Sogo Kenkyusho KK) published 8 June 1984.	1-3
X	WPI Acc. No. 86-237939 & SU 1 210 077 A (Tashkent Poly) published 7 February 1986.	1-3